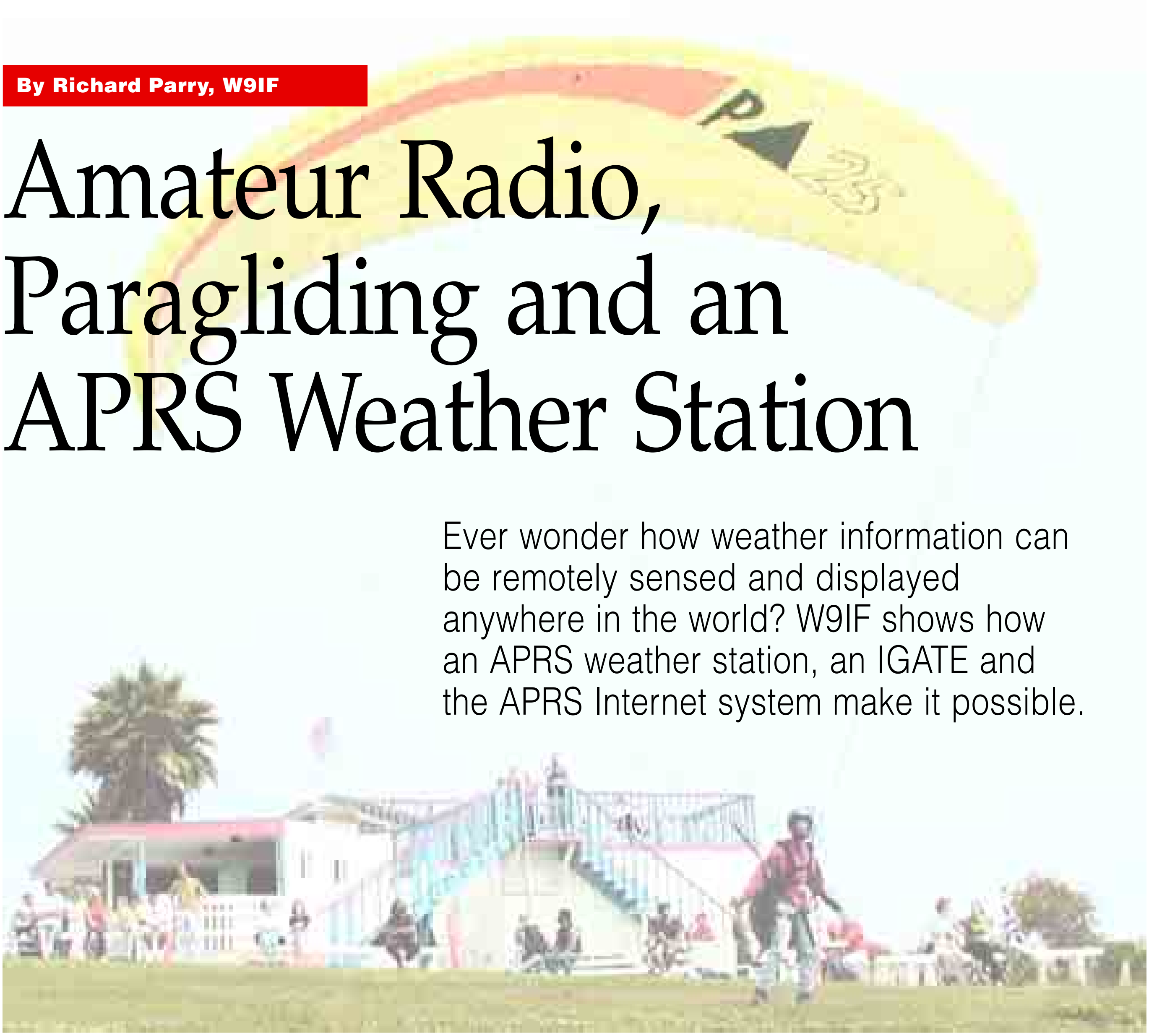
By Richard Parry, W9IF

# Amateur Radio, Paragliding and an APRS Weather Station



Ever wonder how weather information can be remotely sensed and displayed anywhere in the world? W9IF shows how an APRS weather station, an IGATE and the APRS Internet system make it possible.

Amateur Radio is one of the best things that ever happened to me. While building transmitters, antennas, electronic keyers, radioteletype modems, APRS (Automatic Position Reporting System) trackers and a myriad of other projects, ham radio provided an outlet for my creative side and a wonderful learning environment. My high school days were spent installing invisible antennas on the roof of my apartment building in the Bronx, New York City and working DX on 20 meter CW. Those times bring back fond memories of my formative years. Amateur Radio also provided the spark that eventually led to my career as an engineer. More recently, it has allowed me to more fully enjoy the sport of paragliding.

When I tell friends I paraglide, they usually give me a funny look as they think of an "extreme" sport. I'll admit the sport is not for folks afraid of heights, but neither is it limited to the skateboarding generation. It is for anyone wishing to experience the thrill of non-powered flight. It doesn't take a great deal of experience or physical ability. In fact, most pilots take their first flight within a few days of beginning instruction. Paragliding and the sister sport, hang gliding, are referred to as "foot launched" sports. They literally allow anyone to soar like an eagle and reach for the clouds.

The Torrey Pines Gliderport in San Diego, California, where I fly, dates back to 1928. It is one of the premier soaring sites in the United States. National hero Charles Lindbergh flew there. The two-mile ridge, overlooking the Pacific Ocean, gives ample flight opportunity for paragliders, hang gliders, radio-controlled airplanes and full-size sailplanes. The tranquil sea breeze coming off the ocean allows flying with minimal expertise, which makes it a great place to learn. Inland soaring sites are also popular, but unpredictable weather conditions require more skill.

Paragliding allows you to enjoy a short flight along a ridge or a lengthy cross-country flight. Ridge soaring is possible when wind coming from the ocean hits the ridge and is directed upward. The upward movement of air creates lift for flight. With this lift, I have had many flights lasting more than an hour. If you are more adventurous, you can try cross-country paragliding where flights can last all day and cover distances of several hundred miles.

When my wife, Sharon, KC5PVL, and I began taking lessons, it was not uncommon to drive to the Gliderport only to learn that weather conditions would not support flight and we had wasted a trip. We often stayed for hours hoping that conditions would change but all too often they didn't. "Para-waiting" is the name affectionately given to waiting for changing weather conditions. It is no more exciting than watching paint dry.

Like other outdoor sports, you are at the mercy of the weather. However, even when the sun is shining, the temperature is mild and the sky is clear, it doesn't mean you can fly. Flight requires lift. A powered airplane can generate lift anytime, using its engines to provide forward thrust. With sufficient speed, the uneven flow of air over and under the airplane wing results in lift and ultimately...flight. Paragliders do not have a power source, so they rely on Mother Nature for lift. Temperature, humidity, barometric pressure, terrain, wind speed and direction, and numerous other factors determine if flight is possible. Being able to determine those weather conditions while at home, via the Internet, would be a great asset, since it would tell us if flight would be possible. More importantly, it would allow me (and other pilots) to understand those weather conditions, which would ultimately make for safer flights.

## APRS...The Perfect Solution

Weather conditions at my home, 15 miles from the gliderport, tell me nothing about conditions at the gliderport. In fact, weather conditions less than a mile inland from the ocean can be significantly different from conditions on the coast. Therefore, to determine if conditions are sufficient to support flight, we are interested in microclimate weather, which is the condition within a very small geographical area. Microclimate weather conditions can only be determined by a weather station at the site. Unfortunately, the infrastructure at the gliderport is very limited. There are no commercial ac power sources and phone lines are limited. For this reason, an APRS weather station is the perfect solution to provide communications from the gliderport to the local APRS network and, ultimately, to the Internet, where anyone in the world can monitor those conditions.

I am an APRS enthusiast and have installed several APRS mobile trackers, but installing an APRS weather station was breaking new ground for me. It was a learning experience with surprises and setbacks but, in the end, turned out to be a huge success.

The system described here has been operational for many months and has allowed hundreds of pilots to determine flying conditions remotely. The Web site is very popular; it typically gets 200 visits per day and sometimes as many as 400.

## Weather Station Hardware

Many weather station systems are available that support APRS. If you want to build your own, the Tucson Amateur Packet Radio (TAPR) offers the T-238, a low cost APRS weather station developed by Will Beals, NØXGA, and Russ Chadwick, KBØTVJ (**www.tapr.org/tapr/html/Ft238.html**). For a compact low power APRS weather station, see µWeather (**www.rxcomm.net**), developed by KØRX. It is a single board weather station with temperature, pressure and humidity sensors located on a printed circuit board. It also has a real-time clock and generates 1200 baud AFSK weather formatted packets so a TNC is not needed; it connects directly to a radio. Commercial products are also available, such as those from Davis Instruments, RadioShack, Oregon Scientific and Peet Brothers. I selected the Peet Brothers Ultimeter 2000 (hereafter abbreviated U2K). It was picked because of its popularity and the availability of software (*Meteorologica* from Jonathan Bradshaw, N9OXE/M1EUY) that supports both the U2K and *Linu*x. However, that software is not used in the weather station discussed here. [*QST* reviewed the Ultimeter 2100, a similar, but enhanced, version of the 2000, in the January 2003 issue.—*Ed.*]

Purchasing a weather station can be like purchasing a camera. The number of options and "add-ons" is staggering. A rain gauge, sun shield and humidity sensor are a few of the more frequently purchased add-ons. Computer software for logging, displaying and analyzing weather data is also available. You can also purchase a remote modem that interfaces the weather station to a telephone line to allow the system to be remotely accessed by placing a phone call to the unit. Fortunately, for my paragliding weather station, all sensors I needed were included in the base configuration. The U2K comes with an anemometer to sense wind speed and direction and an outdoor temperature sensor. The supplied 40 foot cable connects the anemometer to the control head, and the temperature sensor comes with a 25 foot cable. Extension cables are available, but extending the length of the temperature sensor can result in small errors. A barometric and indoor temperature sensor is also included with the purchase of the weather station; both are located inside the display console, so no additional wiring is needed. Figure 1 provides a block diagram of the key components of the APRS weather station.

There wasn't much I could do about protecting the weather station's outdoor sensors from the harsh Pacific Ocean's salt air, but the electronics (TNC, hand-held transceiver and U2K) needed protection. I gave this a lot of thought and effort. I considered an outdoor sprinkler system enclosure or a weatherproof electrical box. Since the equipment would be inside a small shack, however, it wasn't mandatory that it be completely weatherproof. I decided on a dustproof and waterproof camera enclosure, the kind with thick foam that can be custom cut to safely hold and protect fragile camera equipment. My intent was to close the enclosure securely to keep salt air out. I would also add a desiccant to remove residual moisture. This was a great idea until I remembered the barometric sensor is located inside the U2K. Making the enclosure airtight would result in false pressure readings. I opted to leave the enclosure lid open slightly to allow the pressure inside and outside the enclosure to equalize.

Figure 2 shows the enclosure and the main components of the system, a weather station console, TNC and VHF transceiver.

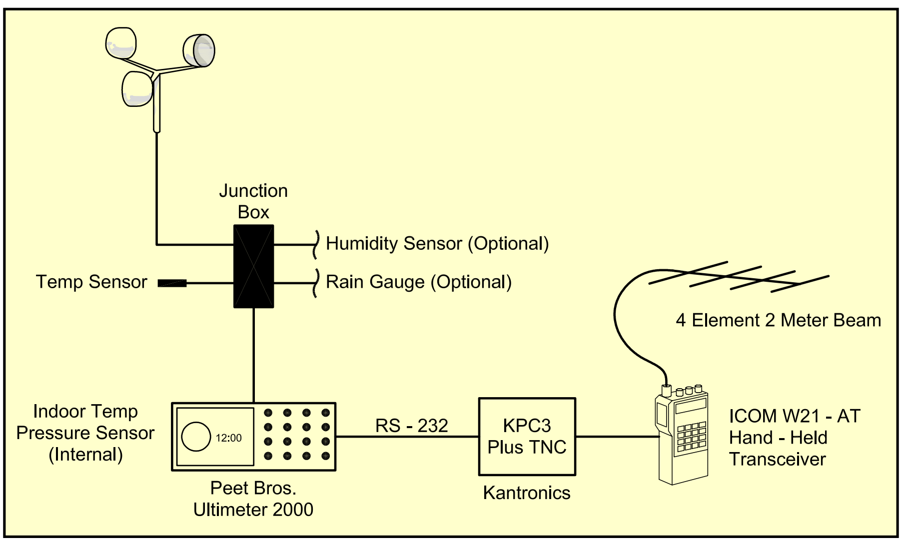



**Figure 1—A block diagram of the W9IF-4 APRS weather station.**

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**Figure 2—Top view of the weather station in its weatherproof enclosure. The Ultimeter 2000 (Peet Brothers) is in the upper left and a Kantronics KPC-3 Plus TNC is in the lower left. An ICOM IC-W21AT on the right is used for communication.**

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**Figure 3—Bottom view of the APRS weather station. The terminal block provides for power distribution, while the junction box in bottom center interfaces the outdoor temperature sensor and anemometer.**

I removed the battery from the radio since it wasn't needed. I could have used an aluminum plate to fasten the equipment, but decided on simple cardboard, which was flexible and easy to work with.

Figure 3 shows the underside of the weather station equipment. A terminal block is used for 12 V dc power distribution. The weather station junction box provides a quick and easy method to connect the weather sensors.

### The San Diego IGATE

The Torrey Pines Gliderport is located in San Diego, a large metropolitan area supported by an active APRS network. However, it is poorly located to support reliable communication. To the west is the Pacific Ocean; RF transmitted in that direction is of no use. To the east are mounds and small hills that attenuate RF signals to the main San Diego APRS network. Initial tests of the W9IF-4 APRS weather station confirmed my fears…most packets were not making it to the network and, therefore, not to an IGATE (Internet Gateway) for delivery to the APRS IS (APRS Internet System). Getting packets to an IGATE is critical. It provides the link to the **findu.com** database, developed by Steve Dimse, K4HG, where weather data is stored and eventually retrieved. Because APRS uses UI (Unnumbered Information) frames, if a packet is lost, it is lost forever; there are no re-transmissions. Every lost packet results in loss of data, so improving packet error rates was imperative in order for this project to be successful.

In some weather conditions, losing packets sporadically might be acceptable. However, when weather conditions change rapidly, every packet of data is valuable since it gives local residents advance notice that can be used to save lives and property. For this reason, APRS weather packets are transmitted at relatively frequent intervals of 5 minutes. Paragliding is unimportant compared to saving lives and property. Nevertheless, having frequent and reliable weather packets allows pilots to react quickly to take advantage of flying opportunities.

Losing packets was a major setback that could best be overcome by adding an APRS IGATE close to the weather-station. I was fortunate that my employer, Qualcomm, Inc is located just 3 miles from the gliderport and was willing to allow me to install the necessary equipment. I was also fortunate that Qualcomm has an amateur radio shack that I could use to house the equipment and connect to the Internet. I set up a dedicated *Linux* system running *aprsd* written by Dale Heatherington, WA4DSY. Once a packet travels the short distance to the IGATE, it is routed to the APRS IS.

Figure 4 shows a block diagram of the W9IF-7 IGATE system. Received packets are sent to the Internet where they are stored in the **findu.com**, MySQL database. When a user wishes to display weather conditions, he or she connects to the weather station Web page (**w9if.net/cgi-bin/torreywx/wx.pl**) and executes a CGI-Perl script, which connects to the **findu.com** database to retrieve the data. Once the data is received, it is analyzed and displayed.

After I installed the IGATE, packet error rates were improved, but still were high. Digging deeper, I discovered that the RF noise level was extremely high at the IGATE receiving station. This was due to the close proximity of the APRS antenna to other commercial antennas located on the roof of the Qualcomm building. Those commercial stations were overloading the front end of the receiver, causing severe intermodulation distortion. The solution was the installation of a 2 meter intermod band-pass filter. I installed a DCI-146-4H filter made by DCI Digital Communications (**www.dci.ca**) and one more problem was solved.

I was sure success was close at hand, but Murphy struck again. Packet error rates were improved after the installation of the intermod filter, but I was still losing almost half of the packets. I was beginning to run out of options. It occurred to me that increasing the transmit signal would help. But rather than increasing the power of the transmitter, I decided to reexamine the antenna system to increase the signal level.

I was using a simple magnetically mounted mobile antenna at the W9IF-4 weather station. It was a good first approxi-

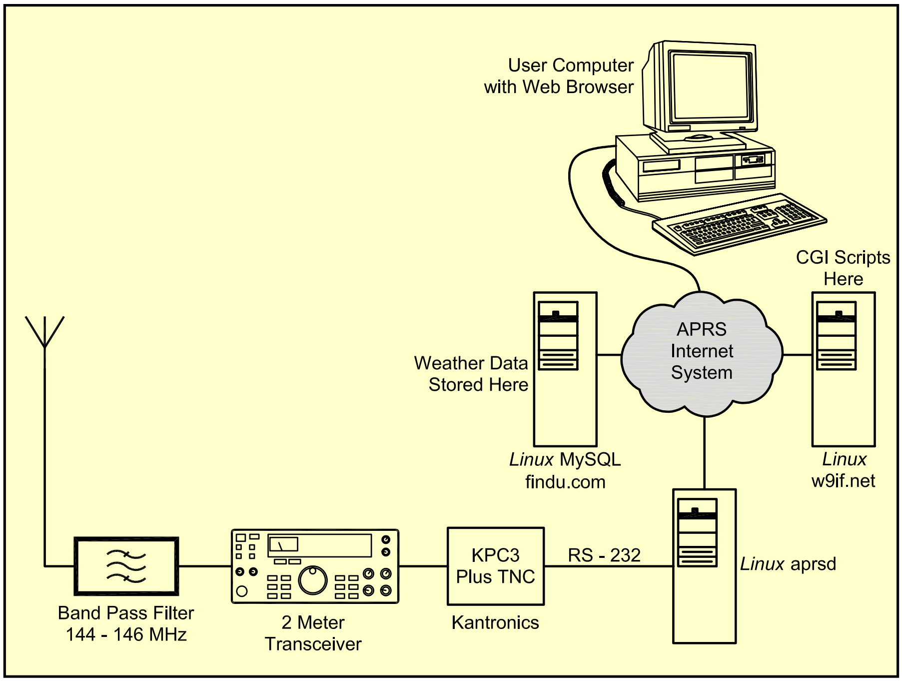


**Figure 4—The APRS weather station IGATE block diagram. The *Linux* system runs *aprsd* software and forwards weather packets to the findu.com database. Weather data is displayed on a user's Web browser after retrieval from the database.**

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**Figure 5—A Kenwood TM-D700A with voice synthesizer provides both visual and aural notification of weather conditions. The D700A speaks wind speed and direction without requiring driver visual interaction.**

mation, but it wasn't doing the job. I decided to change to a 4-element 2 meter Yagi antenna, which would give me gain and direct the RF to the IGATE, rather than sending most of it out over the Pacific Ocean, where it would be wasted. Finally…success! Packet error rates were acceptable…less than 5%.

Installation of a receiving node just 3 miles from the weather station had several advantages. First, since I had installed my own IGATE, I did not need to use the local APRS network to transmit packets to the APRS IS. This meant I could specify a very short APRS path from the weather station TNC, W9IF-4, to the IGATE TNC, W9IF-7. Using an efficient path is particularly important in an APRS weather station application, where packets are broadcast frequently (5-minute intervals). A shorter path means less traffic and therefore more bandwidth for other users.

The second advantage of the installation of the W9IF-7 IGATE is the increased coverage it provides to the metropolitan APRS network. It is configured as a RELAY only digipeater. The weather station, W9IF-4, can also be configured as a RELAY only digipeater, but its remoteness and relative proximity to the IGATE makes its use as a digipeater unnecessary.

WIDE-N digipeaters located on nearby mountaintops that provide wide area coverage are not needed. For this application, the goal is to transfer weather packets to the Internet, which is accomplished efficiently by the W9IF-7 IGATE. Broadcasting weather data by RF to the local network is of little, if any, benefit.

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**Figure 6—A commercial pager can be used to display weather conditions. Here, the display shows that the wind is from the SSW (216°) at 14 mph.**

## Automated Notification

Being able to ascertain weather conditions from anywhere via the Internet using a Web browser is a very powerful tool. But, being able to ascertain weather conditions while mobile would be even nicer. Once again, Amateur Radio provided the perfect solution. By sending an APRS message, I could obtain current weather conditions while in my car.

I programmed my *Linux* machine to connect to the **findu.com** database at 15-minute intervals to retrieve weather conditions. If wind direction and speed met predefined criteria, an APRS message was transmitted to my car.

While any TNC and display would provide this functionality, the Kenwood TM-D700A with an optional built-in voice synthesizer provided a safe, compact and elegant solution. Since the weather conditions were "spoken" by the D700A, I did not have to take my eyes off the road, so it was a particularly convenient and safe way to be notified.

Figure 5 shows the D700A with a typical weather display. The "%" percent symbol preceding the wind direction and wind speed displayed on the face of the D700A specifies that the text be spoken. DIR (wind direction) and SPD (wind speed) are abbreviations used to limit the length of the message and therefore conserve APRS network bandwidth.

The same technique used for sending APRS messages can be applied to notification to a commercial pager or cell phone. Figure 6 shows the results of an e-mail message sent to a pager that displays weather information when I am not connected to the Internet or mobile. A transceiver such as the Kenwood D7 with built-in TNC can provide similar functionality.

## Aeronautical Mobile

Amateur Radio provides the means to determine weather conditions remotely and help pilots determine when conditions are likely to support flight. However, even when one is flying, Amateur Radio is a great asset. It allows pilots to communicate with each other.

The United States Hang Gliding Association (USHGA) is the governing body for hang gliding and paragliding in the US. It has been allocated 151.625, 151.995 and 151.925 MHz for communications use by the FCC.

A radio is more than a convenience when piloting; it is an important link between a student and an instructor. A radio is a requirement; it is vital to allow instructors to provide feedback and instruction to students. When a student graduates, the radio is no longer mandatory, but it is still useful for general communication.

As licensed Amateur Radio operators, my wife and I can operate in the amateur bands. Standard 2 meter simplex frequencies provide an effective means for air-to-air communication. Since we are always within sight of each other, a few mW is more than enough power for reliable communication. We can communicate with other hams via a repeater, but since flying safely is priority one, talking is limited to passing information that directly affects the flight.

Controlling the radio while aeronautically mobile is not an easy task since paragliding requires constant use of both hands. The audio portion of the human interface problem is solved with a small microphone located in the chin portion of the helmet and a speaker in the helmet near the pilot's ear. Figure 7 shows the general location of the equipment.

Controlling the PTT switch of the transceiver is a little more difficult. VOX (voice operated relay) control would appear to be a perfect solution. In practice, it doesn't work well, however. Since not everyone uses a radio, pilots often need to resort to traditional means of communication such as shouting or blowing a whistle to get another pilot's attention. These sounds would result in false trips of the VOX circuit. For this reason, VOX is not used. Control of the transceiver is accomplished using a switch mounted on a Velcro strap that wraps around a finger and using it to control the radio while holding the paraglider's break lines is easy and safe. Figure 8 provides a close-up of the finger PTT switch and connector for the microphone and earpiece.

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**Figure 7—The author ready for aeronautical mobile communication. Speaker and microphone are built into the helmet and a finger PTT switch controls the transceiver, leaving both hands free for flying. Safety is paramount while flying and special equipment is required and is designed toward that end.**

RICHARD PARRY, W9IF


**Figure 8—A view of the finger PTT switch and connector that interfaces the speaker and microphone inside the helmet.**

## Weather Station Caveats

Mark Twain quipped, "Everyone talks about the weather, but no one does anything about it." Unfortunately, our inability to do something about the weather is likely to continue. Predicting weather is hard enough to do without trying to control it.

Weather forecasting requires a sophisticated mathematical model with copiously accurate data to feed that model. Getting accurate data is a formidable task all by itself. One of the myriad problems with predicting the weather is measuring it. I originally took the simplistic view that all I had to do was install a weather station and it would tell me what I wanted to know. I discovered that measuring weather depends heavily on definitions. Two weather stations from different manufacturers can give different readings. In fact, the same weather station can give different readings based on the sampling mode it uses. For example, in the data logging mode, the U2K outputs wind speeds every second which represents instantaneous wind speed. In packet mode, it outputs average wind speed during a 5-minute period.

Other manufacturers use different sampling periods, resulting in still different values. There appears to be little standardization. In the US, for example, the stan-

## Resources

**w9if.net** The author's home page.
**w9if.net/cgi-bin/torreywx/wx.pl** The Torrey Pines Gliderport Weather Page, the basis for this article.
**www.tapr.org/tapr/html/Ft238.html** Web page for the TAPR low cost APRS weather station based on the Dallas Semiconductor 1-wire system.
**www.rxcomm.net** Web page for the µWeather weather station.
**205.156.54.206/asos/obs.htm** An overview of Automated Surface Observation systems.
**205.156.54.206/oso/oso1/oso12/fmh1.htm** The Federal Meteorological Handbook (FMH) Number 1 titled, *Surface Weather Observations and Reports*, dated December 1995 is the definitive US standard for the Aviation Routine Weather Report/Aviation Selected Special Weather Report (METAR/SPECI) code formats.
**www.fiu.edu/orgs/w4ehw/onnhc-wind.html** Weather Volunteer Observers Network at The National Hurricane Center. How to get accurate wind speeds.
**www.flytorrey.com** The Torrey Pines Gliderport home page.

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**Figure 9—Preparing to launch. The APRS weather station antenna and anemometer can be seen in the background.**

dard sampling period for wind measurements is 2 minutes; in Europe it is 10 minutes. A full explanation of wind measurement is outside the scope of this article and I don't claim to have that expertise, but the salient point is that an understanding of how a measurement is taken is important to the understanding of that data.

Sensor placement is yet another variable that greatly affects the data. Weather can vary drastically between locations separated by less than a mile. It also varies with altitude. Measuring wind speed and direction at 1, 10 and 100 meters above ground level can give widely different measurements. For this reason, the National Weather Service (NWS) launches weather balloons daily to measure weather conditions at various altitudes.

A report from the American Society of Testing Materials (ASTM) defines standard techniques for measuring wind speed. It specifies that, "The anemometer and wind vane shall be located at a 10 meter (33 ft) height above level or gently sloping terrain with an open fetch [The distance along open land over which the wind blows.—*Ed*.] of at least 150 meters (500 ft) in all directions, with the largest fetch possible in the prevailing wind direction. Compromise is frequently recognized and acceptable for some sites. Obstacles in the vicinity should be at least ten times their own height distant from the wind sensors."

For most weather station installations, meeting this standard is difficult. Few amateur weather station volunteers have an isolated 30 foot tower. If they do, there is probably a Yagi or quad antenna sitting on top. More common and realistic are rooftop installations. Under these less than ideal conditions, wind flow may be influenced by a variety of factors—a sloping roof, vertical surfaces and structures (chimneys). Due mostly to the remoteness of the Torrey Pines Gliderport, I was able to come close to meeting ASTM requirements. Figure 9 shows the anemometer located on the roof of the gliderport headquarters, which is within 200 feet of the launch site, making it a near ideal location.

The important point of this discussion is that equipment and sensor placement affects the results. For this reason, it is suggested that this information be provided along with the wind data. See the Resources section for several sources that provide additional information on wind sensor placement.

Weather station configuration, weather station firmware, the Web interface and TNC configuration along with the KPC-3 Plus initialization commands can all be found on the ARRL Web page for this article: **www.arrl.org/files/qst-binaries/aprs_weather.zip**.

### Finally...

When I started this project I felt it would be straightforward…a simple weekend exercise or, at worse, it would be up and running in a few weeks. It turned out to be more of an effort than I had intended, but that was mostly due to my ignorance of setting up a weather station and in not understanding its subtle complexities. Murphy's Laws also played some part in my setbacks. However, the results have been well worth the effort and the popularity of the Web site enforces that.

It is important to note that the Torrey Pines Gliderport APRS weather station builds on the work of many Amateur Radio operators. It would not be possible without the APRS protocol developed by Bob Bruninga, WB4APR. Nor would it be possible without the APRS Internet system and **findu.com** server developed by Steve Dimse, K4HG. The APRS IGATE software, *aprsd*, developed by Dale Heatherington, WA4DSY, was also a crucial component.

The APRS SIG mailing list sponsored by TAPR (Tucson Amateur Packet Radio) was an invaluable source of information and encouragement. Special thanks to David Norris, KG9AE, for his weather station expertise and his willingness to Elmer me on the subject. Thanks also to Mike Tortorella, W2IY, for listening to my problems and offering suggestions. To David and Gabe Jebb, my flying instructors, who supported my efforts. Thanks to my employer, Qualcomm, Inc for allowing installation of a San Diego DIGI and IGATE. And lastly to my wife, Sharon, KC5PVL, who introduced me to paragliding and will always be the wind beneath my wing.

*R. Parry, W9IF, was first licensed in 1962 and has held an Amateur Extra class license for most of that time. Richard's formative years in ham radio were spent homebrewing equipment and operating 20 meter CW. Pursuit of a college education and the starting of a family resulted in an absence from ham radio, but he returned and became very active in designing, building, writing about and operating RTTY. He is the author of numerous Amateur Radio articles and he has published in QST, QEX, 73 and the* ARRL/TAPR DCC Proceedings. *Richard holds a BSEE from the University of Illinois, an MBA from Northern Illinois University, an MSCS from North Central College and an FCC General Class Radiotelephone license. He is a software engineer at Qualcomm, Inc in San Diego, California, where he works on wireless telecommunication systems. Richard comes from an Amateur Radio family consisting of his father, WB2ILP, his wife, KC5PVL and his son, KK5SU. You can contact him at* **w9if@arrl.net**.